APPENDIX A

CALCULATIONS OF LANDFILL GAS ENERGY RECOVERY PROJECT COSTS

This Appendix contains sample cost estimates and calculations for three landfill sizes--1, 5, and 10 million metric tons of waste in place. The cost data are intended to illustrate the types of cost items that should be included when evaluating project economics. The actual costs of a specific project are dependent on project configuration, design, equipment selection, location, and site-specific factors. Thus, a qualified engineer should be consulted when considering investing in a landfill gas energy recovery project.

This Appendix contains 20 tables. Tables A.1 through A.14 present costs and calculations for a landfill gas power project, and Tables A.15 through A.20 present costs and calculations for a medium-Btu gas project. Tables A.1 through A.10 contain capital and O&M cost information for each of the landfill sizes. The remainder of the power project tables--Tables A.11 through A.14--contain sample comparisons of expenses and revenues for a 5 million metric ton landfill power project. Project finance and municipal bond finance cases are included.

TABLE A.1 SUMMARY OF ESTIMATED POWER PROJECT CAPITAL COSTS

LANDFILL SIZE Waste in Place	Estimated Net Sustainable LFG Production (mcf/day)	Net Electric Output (kW)	CAPITAL COSTS				
			Installed LFG Collection System ($/kW)	Installed Energy Conversion System ($/kW)	Total Soft Costs + Engineering ($/kW) (a)	Total Capital Requirement ($/kW)	Incremental Capital Requirement ($/kW) (b)
1 million metric tons							
IC Engine	642	984	$638	$1,052	$310	$2,000	$1,283
Combustion Turbine	642	963	$652	$1,412	$359	$2,423	$1,691
5 million metric tons							
IC Engine	2,988	4,934	$423	$958	$294	$1,675	$1,177
Combustion Turbine	2,988	4,727	$442	$1,153	$334	$1,928	$1,409
Combined Cycle CT	2,988	6,763	$309	$1,360	$356	$2,025	$1,658
10 million metric tons							
IC Engine	5,266	8,709	$413	$919	$263	$1,595	$1,109
Combustion Turbine	5,266	8,344	$431	$1,037	$288	$1,756	$1,249
Combined Cycle CT	5,266	12,008	$300	$1,208	$306	$1,813	$1,458

Notes:

Source is cost calculation tables for each size landfill.

All costs are based on net electric (kW) output.

(a) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (6 – 24 mos) and interest during construction.

(b) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.2 ESTIMATED CAPITAL COSTS (1 million Mg case)

Example: Landfill waste in place = 1 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	
OPERATING DATA				
Net sustainable landfill gas production	mcf/day	642	642	(a)
Gross electric output	kW	1,029	1,029	(b)
Auxiliary and compressor loads	kW	46	66	(c)
Net electric output	kW	984	963	
On-line date		6/96	6/96	
Capacity factor (lifetime annual average)		80%	80%	(d)
Annual full load operating hours	hours	7,008	7,008	
Annual electricity generated	kWh	6,895,872	6,748,704	
EQUIPMENT & INSTALLATION COSTS				
Energy Conversion System ($1994)				
Engine, auxiliaries, construction	$000	825	1,050	(e)
Interconnections (elec, water, LFG)	$000	110	110	(f)
Gas compressor	$000	100	200	
Energy conversion system cost	$000	1,035	1,360	
LFG collection system cost ($1994)	$000	628	628	(g)
Engineering ($1994) @ 5.0%	$000	83	99	(h)
CAPITAL REQUIREMENT				
System cost ($1994)	$000	1,746	2,087	
Soft Costs				
Owners costs, escalation, interest		135	142	(i)
Contingency @ 5.0%		87	104	
Total Soft Costs	$000	222	246	
Total Capital Requirement	$000	**1,968**	**2,333**	
(as-spent dollars, 1996 on-line date)	$/kW net	**2,000**	**2,423**	
Incremental Capital Requirement	$000	**1,263**	**1,628**	(j)
(as-spent dollars, 1996 on-line date)	$/kW net	**1,283**	**1,691**	

Notes:

(a) Based on landfill size of approximately 1 million metric tons. [EPA] (mcf = thousand cubic feet)
1 cf landfill gas = 0.5 cf methane

(b) kW = (cf/hr methane) x (1000 Btu/cf) / (13,000 Btu/kWh)

(c) Compressor effects: IC engine--2% parasitic load; CTs--4% parasitic load

(d) Conservative estimated capacity factor over project life. [EPA]

(e) Includes prime mover, generator, plant auxiliaries, construction, LFG modifications, emissions controls.

(f) Assumed to be $100,000 for electric, $10,000 for water.

(g) Calculated based on EPA Exhibit 4-7; includes collection system + flare. [EPA]

(h) Calculated as 5% of conversion and collection system costs.

(i) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (6 mos) and interest during construction.

(j) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.3 ESTIMATED COST OF ELECTRICITY (1 million Mg case)
Project Finance Case

Example: Landfill waste in place = 1 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	
POWER PROJECT COSTS				
Capital Costs (as-spent, 1996 online)				
Conversion system + collection system	$/kW	2,000	2,423	
Conversion system only	$/kW	1,283	1,691	
O&M Costs (1996)				
LFG collection system	c/kWh	1.2	1.2	(a)
Conversion system	c/kWh	1.8	1.5	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)				
Capital charge rate (project finance)		0.136	0.136	(d)
Total Electricity Cost				
Levelized capacity price	c/kWh	3.9	4.7	(e)
1996 O&M price	c/kWh	3.0	2.7	
Royalty Payment	c/kWh	0.5	0.5	
Total 1996 cost of electricity	c/kWh	7.4	7.9	
Incremental Electricity Cost				(f)
Levelized capacity price	c/kWh	2.5	3.3	(e)
1996 O&M price	c/kWh	1.8	1.5	
Royalty Payment	c/kWh	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.8	5.3	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes: 20-year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10-year depreciation.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Conversion system only cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.4 ESTIMATED COST OF ELECTRICITY (1 million Mg case)
Municipal Bond Finance Case

Example: Landfill waste in place = 1 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	
POWER PROJECT COSTS				
Capital Costs (as-spent, 1996 online)				
Conversion system + collection system	$/kW	2,000	2,423	
Conversion system only	$/kW	1,283	1,691	
O&M Costs (1996)				
LFG collection system	c/kWh	1.2	1.2	(a)
Conversion system	c/kWh	1.8	1.5	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)				
Capital charge rate (muni bond finance)		0.111	0.111	(d)
Total Electricity Cost				
Levelized capacity price	c/kWh	3.2	3.8	(e)
1996 O&M price	c/kWh	3.0	2.7	
Royalty Payment	c/kWh	0.5	0.5	
Total 1996 cost of electricity	c/kWh	6.7	7.0	
Incremental Electricity Cost				(f)
Levelized capacity price	c/kWh	2.0	2.7	(e)
1996 O&M price	c/kWh	1.8	1.5	
Royalty Payment	c/kWh	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.3	4.7	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes tax-exempt municipal bond financing at 6.5%.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Conversion system only cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.5 ESTIMATED CAPITAL COSTS (5 million Mg case)

Example: Landfill waste in place =	5	million metric tons			
Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
OPERATING DATA					
Net sustainable landfill gas production	mcf/day	2,988	2,988	2,988	(a)
Gross electric output	kW	5,188	5,188	7,324	(b)
Auxiliary and compressor loads	kW	254	461	561	(c)
Net electric output	kW	4,934	4,727	6,763	
On-line date		6/96	6/96	6/96	
Capacity factor (lifetime annual average)		80%	80%	80%	(d)
Annual full load operating hours	hours	7,008	7,008	7,008	
Annual electricity generated	kWh	34,577,472	33,126,816	47,395,104	
EQUIPMENT & INSTALLATION COSTS					
Energy Conversion System ($1994)					
Engine, auxiliaries, construction	$000	4,075	4,300	7,950	(e)
Interconnections (elec, water, LFG)	$000	400	400	500	(f)
Gas compressor	$000	250	750	750	
Energy conversion system cost	$000	4,725	5,450	9,200	
LFG collection system cost ($1994)	$000	2,088	2,088	2,088	(g)
Engineering ($1994) @ 5.0%	$000	341	377	564	(h)
CAPITAL REQUIREMENT					
System cost ($1994)	$000	7,154	7,915	11,853	
Soft Costs					
Owners costs, escalation, interest		751	804	1,248	(i)
Contingency @ 5.0%		358	396	593	
Total Soft Costs	$000	1,109	1,200	1,841	
Total Capital Requirement	$000	**8,263**	**9,115**	**13,694**	
(as-spent dollars, 1996 on-line date)	$/kW net	**1,675**	**1,928**	**2,025**	
Incremental Capital Requirement	$000	**5,807**	**6,659**	**11,216**	(j)
(as-spent dollars, 1996 on-line date)	$/kW net	**1,177**	**1,409**	**1,658**	

Notes:

(a) Based on landfill size of approximately 5 million metric tons. [EPA] (mcf = thousand cubic feet)
1 cf landfill gas = 0.5 cf methane

(b) kW = (cf/hr methane) x (1000 Btu/cf) / (generator Btu/kWh)

(c) Compressor effects: IC engine--2% parasitic load; CTs--6% parasitic load

(d) Conservative estimated capacity factor over project life. [EPA]

(e) Includes prime mover, generator, plant auxiliaries, construction, LFG modifications, emissions controls.

(f) Assumed to be $350,000 to $450,000 for electric, $50,000 for water.

(g) Calculated based on EPA Exhibit 4-7; includes collection system + flare. [EPA]

(h) Calculated as 5% of conversion and collection system costs.

(i) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (12 - 18 mos) and interest during construction.

(j) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.6 ESTIMATED COST OF ELECTRICITY (5 million Mg case)
Project Finance Case

Example: Landfill waste in place = 5 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
POWER PROJECT COSTS					
Capital Costs (as-spent, 1996 online)					
Conversion system + collection system	$/kW	1,675	1,928	2,025	
Conversion system only	$/kW	1,177	1,409	1,658	
O&M Costs (1996)					
LFG collection system	c/kWh	0.5	0.5	0.5	(a)
Conversion system	c/kWh	1.8	1.5	1.6	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)					
Capital charge rate (project finance)		0.136	0.136	0.136	(d)
Total Electricity Cost					
Levelized capacity price	c/kWh	3.2	3.7	3.9	(e)
1996 O&M price	c/kWh	2.3	2.0	2.1	
Royalty payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	6.0	6.2	6.5	
Incremental Electricity Cost					(f)
Levelized capacity price	c/kWh	2.3	2.7	3.2	(e)
1996 O&M price	c/kWh	1.8	1.5	1.6	
Royalty payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.6	4.7	5.3	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes: 20-year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10-year depreciation.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Incremental Electricity Cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.7 ESTIMATED COST OF ELECTRICITY (5 million Mg case)
Municipal Bond Finance Case

Example: Landfill waste in place = 5 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
POWER PROJECT COSTS					
Capital Costs (as-spent, 1996 online)					
Conversion system + collection system	$/kW	1,675	1,929	2,025	
Conversion system only (incremental)	$/kW	1,177	1,409	1,658	
O&M Costs (1996)					
LFG collection system	c/kWh	0.5	0.5	0.5	(a)
Electric generation system	c/kWh	1.8	1.5	1.6	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)					
Capital charge rate (muni bond finance)		0.111	0.111	0.111	(d)
Total Electricity Cost					
Levelized capacity price	c/kWh	2.7	3.1	3.2	(e)
1996 O&M price	c/kWh	2.3	2.0	2.1	
Royalty payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	5.5	5.6	5.8	
Incremental Electricity Cost					(f)
Levelized capacity price	c/kWh	1.9	2.2	2.6	(e)
1996 O&M price	c/kWh	1.8	1.5	1.6	
Royalty payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.2	4.2	4.7	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes tax-exempt municipal bond financing at 6.5%.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Incremental Electricity Cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.8 ESTIMATED CAPITAL COSTS (10 million Mg case)

Example: Landfill waste in place = 10 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
OPERATING DATA					
Net sustainable landfill gas production	mcf/day	5,266	5,266	5,266	(a)
Gross electric output	kW	9,142	9,142	12,907	(b)
Auxiliary and compressor loads	kW	433	799	899	(c)
Net electric output	kW	8,709	8,344	12,008	
On-line date		6/96	6/96	6/96	
Capacity factor (lifetime annual average)		80%	80%	80%	(d)
Annual full load operating hours	hours	7,008	7,008	7,008	
Annual electricity generated	kWh	61,032,672	58,474,752	84,152,064	
EQUIPMENT & INSTALLATION COSTS					
Energy Conversion System ($1994)					
Engine, auxiliaries, construction	$000	7,200	7,350	13,100	(e)
Interconnections (elec, water, LFG)	$000	400	400	500	(f)
Gas compressor	$000	400	900	900	
Energy conversion system cost	$000	8,000	8,650	14,500	
LFG collection system cost ($1994)	$000	3,599	3,599	3,599	(g)
Engineering ($1994) @ 5.0%	$000	580	612	905	(h)
CAPITAL REQUIREMENT					
System cost ($1994)	$000	12,179	12,861	19,004	
Soft Costs					
Owners costs, escalation, interest		1,103	1,150	1,820	(i)
Contingency @ 5.0%		609	643	950	
Total Soft Costs	$000	1,711	1,793	2,770	
Total Capital Requirement	$000	**13,890**	**14,654**	**21,774**	
(as-spent dollars, 1996 on-line date)	$/kW net	**1,595**	**1,756**	**1,813**	
Incremental Capital Requirement	$000	**9,658**	**10,422**	**17,504**	(j)
(as-spent dollars, 1996 on-line date)	$/kW net	**1,109**	**1,249**	**1,458**	

Notes:

(a) Based on landfill size of approximately 5 million metric tons. [EPA] (mcf = thousand cubic feet)
1 cf landfill gas = 0.5 cf methane

(b) Calculated according to EPA formula: kW = (cf/hr methane) x (1000 Btu/cf) / generator Btu/kWh)

(c) Compressor effects: IC engine--2% parasitic load; CTs--6% parasitic load

(d) Conservative estimated capacity factor over project life. [EPA]

(e) Includes prime mover, generator, plant auxiliaries, construction, LFG modifications, emissions controls.

(f) Assumed to be $350,000 to $450,000 for electric, $50,000 for water.

(g) Calculated based on EPA Exhibit 4-7; includes collection system + flare. [EPA]

(h) Calculated as 5% of conversion and collection system costs.

(i) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (18 mos) and interest during construction.

(j) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.9 ESTIMATED COST OF ELECTRICITY (10 million Mg case)
Project Finance Case

Example: Landfill waste in place = 10 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
POWER PROJECT COSTS					
Capital Costs (as-spent, 1996 online)					
Conversion system + collection system	$/kW	1,595	1,756	1,813	
Conversion system only	$/kW	1,109	1,249	1,458	
O&M Costs (1996)					
LFG collection system	c/kWh	0.4	0.4	0.4	(a)
Conversion system	c/kWh	1.8	1.3	1.5	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)					
Capital charge rate (project finance)		0.136	0.136	0.136	(d)
Total Electricity Cost					
Levelized capacity price	c/kWh	3.1	3.4	3.5	(e)
1996 O&M price	c/kWh	2.2	1.7	1.9	
Royalty Payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	5.8	5.6	5.9	
Incremental Electricity Cost					(f)
Levelized capacity price	c/kWh	2.2	2.4	2.8	(e)
1996 O&M price	c/kWh	1.8	1.3	1.5	
Royalty Payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.5	4.2	4.8	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes: 20-year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10-year depreciation.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Conversion system only cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.10 ESTIMATED COST OF ELECTRICITY (10 million Mg case)
Municipal Bond Finance Case

Example: Landfill waste in place = 10 million metric tons

Cost Category	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
POWER PROJECT COSTS					
Capital Costs (as-spent, 1996 online)					
Conversion system + collection system	$/kW	1,595	1,756	1,813	
Conversion system only	$/kW	1,109	1,249	1,458	
O&M Costs (1996)					
LFG collection system	c/kWh	0.4	0.4	0.4	(a)
Conversion system	c/kWh	1.8	1.3	1.5	(b)
Royalty Payments (1996)	c/kWh	0.5	0.5	0.5	(c)
FIRST YEAR COST OF ELECTRICITY (1996)					
Capital charge rate (muni bond finance)		0.111	0.111	0.111	(d)
Total Electricity Cost					
Levelized capacity price	c/kWh	2.5	2.8	2.9	(e)
1996 O&M price	c/kWh	2.2	1.7	1.9	
Royalty Payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	5.2	5.0	5.3	
Incremental Electricity Cost					(f)
Levelized capacity price	c/kWh	1.8	2.0	2.3	(e)
1996 O&M price	c/kWh	1.8	1.3	1.5	
Royalty Payment	c/kWh	0.5	0.5	0.5	
Total 1996 cost of electricity	c/kWh	4.1	3.8	4.3	

Notes:

(a) Based on EPA estimate for collection + flare systems (Exhibit 4-7), in $1996. [EPA]

(b) Based on O&M estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations-Technology and Economics," and in EPA Report to Congress (Exhibit 4-7).

(c) Royalty payments to the landfill owner are estimated to be 10% of revenues (4.9 c/kWh).

(d) Assumes tax-exempt municipal bond financing at 6.5%.

(e) Calculated by multiplying capital $/kW by CCR and dividing by annual hours of operation.

(f) Conversion system only cost does not include capital and O&M costs associated with LFG collection system.

TABLE A.11 COMPARISON OF PROJECT REVENUES & EXPENSES (1 st Year)

Example: Landfill waste in place = 5 million metric tons

	Units	IC Engine	Combustion Turbine	Combined Cycle CT
Revenues	c/kWh	4.9	4.9	4.9
PROJECT FINANCE CASE				
Expenses (including Owner's Return)				
Total	c/kWh	6.0	6.2	6.5
Incremental	c/kWh	4.6	4.7	5.3
Revenues Minus Expenses				
Total	c/kWh	(1.1)	(1.3)	(1.6)
Incremental	c/kWh	0.3	0.2	(0.4)
1996 Tax Credit	c/kWh	1.3	1.3	0.9
Estimated Surplus (Shortfall) Cash Flow After Taxes and Owner's Return				
Total Cost Basis	c/kWh	0.2	0.0	(0.7)
	$000	$69	$0	($332)
Incremental Cost Basis	c/kWh	1.6	1.5	0.5
	$000	$553	$497	$237
MUNICIPAL BOND FINANCE CASE				
Expenses (including financing costs)				
Total	c/kWh	5.0	5.1	5.3
Incremental	c/kWh	3.7	3.7	4.2
Revenues Minus Expenses				
Total	c/kWh	(0.1)	(0.2)	(0.4)
Incremental	c/kWh	1.2	1.2	0.7
1996 REPI Subsidy	c/kWh	0.0	0.0	0.0
Estimated Surplus (Shortfall) Cash Flow After Taxes and Financing Expenses				
Total Cost Basis	c/kWh	(0.1)	(0.2)	(0.4)
	$000	($35)	($66)	($190)
Incremental Cost Basis	c/kWh	1.2	1.2	0.7
	$000	$415	$398	$332

Notes:

See Tables A.12–A.14 for notes on calculations.

TABLE A.12 EXAMPLE POWER PROJECT REVENUES (1st Year)

Example: Landfill waste in place = 5 million metric tons

	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
PROJECT OPERATING DATA					
Net sustainable landfill gas production	mcf/day	2,988	2,988	2,988	(a)
Gross electric output	kW	5,188	5,188	7,324	
Net electric output	kW	4,934	4,727	6,763	
Annual electricity generated	kWh	34,577,472	33,126,816	47,395,104	
Electricity used on−site	kWh	3,000,000	3,000,000	3,000,000	(b)
Net electricity sold to utility	kWh	31,577,472	30,126,816	44,395,104	
ANNUAL REVENUES					
Electricity Sales to Utility in 1st Year	$000	$1,522	$1,452	$2,140	(c)
Electricity Sales On−Site in 1st Year	$000	$177	$177	$177	(d)
Total Annual Revenues	$000	$1,699	$1,629	$2,317	
REVENUES ON PER kWh BASIS	c/kWh	4.9	4.9	4.9	(e)

Notes:

(a) Calculated using statistical model 4.2 in EPA Report to Congress. [EPA] The resulting methane production estimate is within the range predicted by the models presented in Part I.

(b) Assumed for example purposes.

(c) Product of utility sales kWh and assumed 1996 buyback electricity rate of 4.8 c/kWh.

(d) Product of on−site sales kWh and assumed 1996 retail electricity rate of 5.9 c/kWh.

(e) Total annual revenues divided by total kWh generated.

TABLE A.13 COMPARISON OF PROJECT REVENUES & EXPENSES (1 st Year) Project Finance Case

Example: Landfill waste in place = 5 million metric tons

	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
REVENUES	c/kWh	4.9	4.9	4.9	(a)
EXPENSES (including Owner's Return)					(b)
Total	c/kWh	6.0	6.2	6.5	
Incremental	c/kWh	4.6	4.7	5.3	
REVENUES MINUS EXPENSES					
Total	c/kWh	(1.1)	(1.3)	(1.6)	
Incremental	c/kWh	0.3	0.2	(0.4)	
1996 TAX CREDIT					
	$/MMBtu	1.049	1.049	1.049	(c)
	c/kWh	1.3	1.3	0.9	(d)
ESTIMATED SURPLUS (SHORTFALL) CASH AFTER TAXES & OWNER'S RETURN					(e)
Total Cost Basis	c/kWh	0.2	0.0	(0.7)	
	$000	$69	$0	($332)	(f)
Incremental Cost Basis	c/kWh	1.6	1.5	0.5	
	$000	$553	$497	$237	

Notes:

(a) Calculated in Table A.12

(b) Calculated in Table A.6. Income taxes, property taxes, and owner's 15% return on equity are included in these expenses.

(c) Based on a tax credit of $0.979/MMBtu ($1994) escalated for 2 years @ 3.5%. [PUR]
If only 60% of tax credit is applied to project, credit drops by about 0.5 c/kWh, or about $173,000.

(d) Calculated by multiplying by an electric heat rate of 12.0 MMBtu/MWh for the IC and CT, and by 8.5 MMBtu/MWh for the combined cycle CT.

(e) Estimated Income is net of income taxes, property taxes, administrative expenses, and owner's 15% return on equity. A negative value indicates that first-year cash flow does not cover the owner's desired 15% return. It is assumed that the project/owner has sufficient tax liability to be able to take full advantage of the tax credit. In many cases, only about 60% of the tax credit can be used.

TABLE A.14 COMPARISON OF PROJECT REVENUES & EXPENSES (1 st Year) Municipal Bond Finance Case

Example: Landfill waste in place = 5 million metric tons

	Units	IC Engine	Combustion Turbine	Combined Cycle CT	
REVENUES	c/kWh	4.9	4.9	4.9	(a)
EXPENSES					(b)
Total	c/kWh	5.0	5.1	5.3	
Incremental	c/kWh	3.7	3.7	4.2	
REVENUES MINUS EXPENSES					
Total	c/kWh	(0.1)	(0.2)	(0.4)	
Incremental	c/kWh	1.2	1.2	0.7	
1996 REPI SUBSIDY	c/kWh	0.0	0.0	0.0	
ESTIMATED SURPLUS (SHORTFALL) CASH AFTER TAXES & FINANCING EXPENSES					
Total Cost Basis	c/kWh	(0.1)	(0.2)	(0.4)	(c)
	$000	($35)	($66)	($190)	
Incremental Cost Basis	c/kWh	1.2	1.2	0.7	
	$000	$415	$398	$332	

Notes:

(a) Calculated in Table A.12

(b) Expenses include the financing costs associated with issuing tax-exempt municipal bonds with a 6.5% interest rate (see Table A.7)

(c) Estimated Income is net of property taxes, administrative expenses, and bond financing expenses. A positive value indicates that first-year cash flow exceeds expenses, including the bond debt service expenses.

TABLE A.15 ESTIMATED MEDIUM–BTU PROJECT CAPITAL COSTS (1 million Mg case)

Example: Landfill waste in place = 1 million metric tons

Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
OPERATING DATA				
Net sustainable landfill gas production	mcf/day	642	642	(a)
Net fuel output (MMBtu)	MMBtu/day	321	321	(b)
On–line date		6/96	6/96	
Capacity factor (lifetime annual average)		90%	40%	(c)
Annual full load operating hours	hours	7,884	3,504	
Annual volume of gas sold	MMBtu	105,488	46,884	
EQUIPMENT & INSTALLATION COSTS				
Gas Delivery System ($1994)				
Condensate removal/filtration	$000	8	8	(d)
Compressor/Blower station	$000	75	75	(e)
Pipeline interconnect	$000	350	350	(f)
Fuel burning equipment conversion	$000	150	150	(g)
Gas delivery system cost ($1994)		583	583	
LFG collection system cost ($1994)	$000	628	628	(h)
Engineering ($1994)	$000	61	61	(i)
CAPITAL REQUIREMENT				
System cost ($1994)	$000	1,271	1,271	
System cost ($1996)	$000	1,362	1,362	
Soft costs($1996)				
Owners costs, escalation, interest		85	85	(j)
Contingency @5.0%		68	68	
Total Soft Costs	$000	153	153	
Total Capital Requirement (as–spent dollars, 1996 on–line date)	$000	1,515	1,515	
Incremental Capital Requirement	$000	729	729	(k)

Notes:

(a) Based on landfill size of approximately 1 metric ton.[EPA]
(b) Assumes landfill gas has 500 Btu/cf, or 1 cf landfill gas = 0.5 cf methane.
(c) Assumes baseload user has a year–round need for gas, and heat load user only uses gas in the five winter months.
(d) Based on an estimate obtained from Perry Equipment for liquid and solid filtration system.
(e) Based on estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations – Technology and Economics", and in Augenstein and Pacey, "Landfill Gas Energy Utilization: Technology Options and Case Studies"
(f) Based on the cost of a one mile pipeline (pipeline costs can range from $250,000 to $500,000 per mile).
(g) Based on the cost of retrofitting one boiler.[PTI]
(h) Calculated based on EPA Exhibit 4–7; includes collection system + flare. [EPA]
(i) Calculated as 5% of conversion and collection costs.
(j) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (6 months) and interest during construction.
(k) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.16 ESTIMATED COST OF MEDIUM–BTU GAS (1M Mg case)

Example: Landfill waste in place =		1 million metric tons		
Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
GAS PRODUCTION COSTS				
Capital Costs (as–spent, 1996 online)				(a)
Total capital requirement	$/MMBtu	14.36	32.31	
Incremental capital requirement	$/MMBtu	6.91	15.56	
O&M Costs (1996)				
LFG collection system	$/MMBtu	0.84	1.89	(b)
Gas delivery system	$/MMBtu	0.11	0.26	(c)
Tax Credit (1996)	$/MMBtu	1.049	1.049	(d, h)
FIRST YEAR COST OF GAS (1996)				
Capital charge rate		0.136	0.136	(e)
Total Gas Cost				
Levelized capacity price	$/MMBtu	1.95	4.39	(f)
1996 O&M price	$/MMBtu	0.95	2.14	
Total 1996 cost of gas	$/MMBtu	2.91	6.54	
Cost of gas including tax credit	$/MMBtu	1.86	5.49	
Incremental Gas Cost				(g)
Levelized capacity price	$/MMBtu	0.94	2.12	
1996 O&M price	$/MMBtu	0.11	0.26	
Total 1996 cost of gas	$/MMBtu	1.05	2.37	
Cost of gas including tax credit	$/MMBtu	0.01	1.32	

Notes:

(a) Assumes annual gas sales of 105,488 MMBtu to baseload user and 46,884 MMBtu to heat load user.

(b) Based on EPA estimate for collection + flare systems (Exhibit 4–7), escalated to $1996. [EPA]

(c) Based on pipeline delineation costs and minor filtration system maintenance costs. [Augenstein and Pacey]

(d) Based on a tax credit value of $0.979/MMBtu ($1994), escalated for 2 years. [PUR]

(e) Assumes: 20–year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10–year depreciation

(f) Calculated by multiplying capital $/MMBtu by CCR.

(g) Incremental Gas Cost does not include capital and O&M costs associated with LFG collection system.

(h) Assumes total value of tax credit goes to the project. In some cases, only a percentage of the tax credit value will be credited to the project due to transaction costs associated with transferring the credits to a third party. For example, 60% of the tax credit may be realized by the project developer; therefore, the value of the tax credit would only be (60% * $1.049), or $0.63/MMBtu.

TABLE A.17 ESTIMATED MEDIUM–BTU PROJECT CAPITAL COSTS (5 million Mg case)

Example: Landfill waste in place = 5 million metric tons

Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
OPERATING DATA				
Net sustainable landfill gas production	mcf/day	2,988	2,988	(a)
Net fuel output (MMBtu)	MMBtu/day	1,494	1,494	(b)
On–line date		6/96	6/96	
Capacity factor (lifetime annual average)		90%	40%	(c)
Annual full load operating hours	hours	7,884	3,504	
Annual volume of gas sold	MMBtu	490,811	218,138	
EQUIPMENT & INSTALLATION COSTS				
Gas Delivery System ($1994)				
Condensate removal/filtration	$000	15	15	(d)
Compressor/Blower station	$000	100	100	(e)
Pipeline interconnect	$000	350	350	(f)
Fuel burning equipment conversion	$000	150	150	(g)
Gas delivery system cost ($1994)		615	615	
LFG collection system cost ($1994)	$000	2,098	2,098	(h)
Engineering ($1994)	$000	136	136	(i)
CAPITAL REQUIREMENT				
System cost ($1994)	$000	2,848	2,848	
System cost ($1996)	$000	3,051	3,051	
Soft costs($1996)				
Owners costs, escalation, interest		190	190	(j)
Contingency @5.0%		153	153	
Total Soft Costs	$000	343	343	
Total Capital Requirement (as–spent dollars, 1996 on–line date)	$000	3,394	3,394	
Incremental Capital Requirement	$000	769	769	(k)

Notes:

(a) Based on landfill size of approximately 5 metric tons.[EPA]
(b) Assumes landfill gas has 500 Btu/cf, or 1 cf landfill gas = 0.5 cf methane.
(c) Assumes baseload user has a year–round need for gas, and heat load user only uses gas in the five winter months.
(d) Based on an estimate obtained from Perry Equipment for liquid and solid filtration system.
(e) Based on estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations – Technology and Economics", and in Augenstein and Pacey, "Landfill Gas Energy Utilization: Technology Options and Case Studies"
(f) Based on the cost of a one mile pipeline (pipeline costs can range from $250,000 to $500,000 per mile).
(g) Based on the cost of retrofitting one boiler.[PTI]
(h) Calculated based on EPA Exhibit 4–7; includes collection system + flare. [EPA]
(i) Calculated as 5% of conversion and collection costs.
(j) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (6 months) and interest during construction.
(k) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.18 ESTIMATED COST OF MEDIUM-BTU GAS (5M Mg case)

Example: Landfill waste in place = 5 million metric tons

Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
GAS PRODUCTION COSTS				
Capital Costs (as-spent, 1996 online)				(a)
Total capital requirement	$/MMBtu	6.92	15.56	
Incremental capital requirement	$/MMBtu	1.57	3.53	
O&M Costs (1996)				
LFG collection system	$/MMBtu	0.31	0.70	(b)
Gas delivery system	$/MMBtu	0.02	0.06	(c)
Tax Credit (1996)	$/MMBtu	1.049	1.049	(d, h)
FIRST YEAR COST OF GAS (1996)				
Capital charge rate		0.136	0.136	(e)
Total Gas Cost				
Levelized capacity price	$/MMBtu	0.94	2.12	(f)
1996 O&M price	$/MMBtu	0.34	0.75	
Total 1996 cost of gas	$/MMBtu	1.28	2.87	
Cost of gas including tax credit	$/MMBtu	0.23	1.82	
Incremental Gas Cost				(g)
Levelized capacity price	$/MMBtu	0.21	0.48	
1996 O&M price	$/MMBtu	0.02	0.06	
Total 1996 cost of gas	$/MMBtu	0.24	0.53	
Cost of gas including tax credit	$/MMBtu	(0.81)	(0.51)	

Notes:

(a) Assumes annual gas sales to baseload user of 490,811 MMBtu and sales of 218,138 MMBtu to heat load user.
(b) Based on EPA estimate for collection + flare systems (Exhibit 4-7), escalated to $1996. [EPA]
(c) Based on pipeline delineation costs and minor filtration system maintenance costs. [Augenstein and Pacey]
(d) Based on a tax credit value of $0.979/MMBtu ($1994), escalated for 2 years. [PUR]
(e) Assumes: 20-year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10-year depreciation
(f) Calculated by multiplying capital $/MMBtu by CCR.
(g) Incremental Gas Cost does not include capital and O&M costs associated with LFG collection system.
(h) Assumes total value of the tax credit goes to the project. In some cases, only a percentage of the tax credit value will be credited to the project due to transaction costs associated with transferring the credits to a third party. For example, 60% of the credit may be realized by the project developer; therefore, the value of the tax credit would only be (60% * $1.049), or $0.63/MMBtu.

TABLE A.19 ESTIMATED MEDIUM–BTU PROJECT CAPITAL COSTS (10 million Mg case)

Example: Landfill waste in place = 10 million metric tons

Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
OPERATING DATA				
Net sustainable landfill gas production	mcf/day	5,266	5,266	(a)
Net fuel output (MMBtu)	MMBtu/day	2,633	2,633	(b)
On–line date		6/96	6/96	
Capacity factor (lifetime annual average)		90%	40%	(c)
Annual full load operating hours	hours	7,884	3,504	
Annual volume of gas sold	MMBtu	864,917	384,408	
EQUIPMENT & INSTALLATION COSTS				
Gas Delivery System ($1994)				
Condensate removal/filtration	$000	25	25	(d)
Compressor/Blower station	$000	200	200	(e)
Pipeline interconnect	$000	350	350	(f)
Fuel burning equipment conversion	$000	150	150	(g)
Gas delivery system cost ($1994)		725	725	
LFG collection system cost ($1994)	$000	3,599	3,599	(h)
Engineering ($1994)	$000	216	216	(i)
CAPITAL REQUIREMENT				
System cost ($1994)	$000	4,540	4,540	
System cost ($1996)	$000	4,863	4,863	
Soft costs($1996)				
Owners costs, escalation, interest		303	303	(j)
Contingency @5.0%		243	243	
Total Soft Costs	$000	546	546	
Total Capital Requirement (as–spent dollars, 1996 on–line date)	$000	5,410	5,410	
Incremental Capital Requirement	$000	907	907	(k)

Notes:

(a) Based on landfill size of approximately 10 metric tons.[EPA]
(b) Assumes landfill gas has 500 Btu/cf, or 1 cf landfill gas = 0.5 cf methane.
(c) Assumes baseload user has a year–round need for gas, and heat load user only uses gas in the five winter months.
(d) Based on an estimate obtained from Perry Equipment for liquid and solid filtration system.
(e) Based on estimates published by Wolfe & Maxwell in "Commercial Landfill Recovery Operations – Technology and Economics", and in Augenstein and Pacey, "Landfill Gas Energy Utilization: Technology Options and Case Studies"
(f) Based on the cost of a one mile pipeline (pipeline costs can range from $250,000 to $500,000 per mile).
(g) Based on the cost of retrofitting one boiler.[PTI]
(h) Calculated based on EPA Exhibit 4–7; includes collection system + flare. [EPA]
(i) Calculated as 5% of conversion and collection costs.
(j) Included are owners' costs (legal, permitting, insurance, taxes), escalation during construction (6 months) and interest during construction.
(k) Excludes capital and soft costs associated with the LFG collection system.

TABLE A.20 ESTIMATED COST OF MEDIUM–BTU GAS (10M Mg case)

Example: Landfill waste in place = 10 million metric tons

Cost Category	Units	Baseload user (continuous)	Heat load user (seasonal)	
GAS PRODUCTION COSTS				
Capital Costs (as–spent, 1996 online)				(a)
Total capital requirement	$/MMBtu	6.25	14.07	
Incremental capital requirement	$/MMBtu	1.05	2.36	
O&M Costs (1996)				
LFG collection system	$/MMBtu	0.25	0.57	(b)
Gas delivery system	$/MMBtu	0.01	0.03	(c)
Tax Credit (1996)	$/MMBtu	1.049	1.049	(d, h)
FIRST YEAR COST OF GAS (1996)				
Capital charge rate		0.136	0.136	(e)
Total Gas Cost				
Levelized capacity price	$/MMBtu	0.85	1.91	(f)
1996 O&M price	$/MMBtu	0.27	0.60	
Total 1996 cost of gas	$/MMBtu	1.12	2.51	
Cost of gas including tax credit	$/MMBtu	0.07	1.46	
Incremental Gas Cost				(g)
Levelized capacity price	$/MMBtu	0.14	0.32	
1996 O&M price	$/MMBtu	0.01	0.03	
Total 1996 cost of gas	$/MMBtu	0.16	0.35	
Cost of gas including tax credit	$/MMBtu	(0.89)	(0.70)	

Notes:

(a) Assumes annual gas sales to baseload user of 864,917 MMBtu and sales of 384,408 MMBtu to heat load user.
(b) Based on EPA estimate for collection + flare systems (Exhibit 4–7), escalated to $1996. [EPA]
(c) Based on pipeline delineation costs and minor filtration system maintenance costs. [Augenstein and Pacey]
(d) Based on a tax credit value of $0.979/MMBtu ($1994), escalated for 2 years. [PUR]
(e) Assumes: 20–year life, project finance with a 80/20 debt/equity ratio, 9% interest on debt; includes 15% return on equity; 10–year depreciation
(f) Calculated by multiplying capital $/MMBtu by CCR.
(g) Incremental Gas Cost does not include capital and O&M costs associated with LFG collection system.
(h) Assumes total value of tax credit goes to the project. In some cases, only a percentage of the tax credit value will be credited to the project due to transaction costs associated with transferring the credits to a third party. For example, 60% of the credit may be realized by the project developer; therefore, the value of the tax credit would only be (60% * $1.049), or $0.63/MMBtu.

APPENDIX B

LIST OF U.S. EPA OFFICES

U.S. Environmental Protection Agency Offices

EPA Region	EPA Address	States Included in Region	Regional Contact	Phone	Fax
	Landfill Methane Program 401 M St., SW, 6202J Washington, DC 20460	All		202-233-9042	
1	John F.Kennedy Federal Bldg. One Congress Street Boston, MA 02203	CT, ME, MA, NH, RI, VT	Jeanne Cosgrove	617-565-9451	617-565-4940
2	Federal Office Bldg. 26 Federal Plaza New York, NY 10278	NJ, NY, Puerto Rico, Virgin Islands	Christine DeRosa	212-637-4022	212-637-3998
3	Curtis Building Sixth and Walnut Streets Philadelphia, PA 19106	DE, DC, MD, PA, VA, WV	Jim Topsale	215-566-2190	215-566-2124
4	345 Courtland, NE Atlanta, GA 30308	AL, FL, GA, MS, KY, NC, SC, TN	Scott Davis	404-347-5014 Ext. 4144	404-347-3059
5	230 South Dearborn St. Chicago, IL 60604	IL, MN, MI, OH, IN, WI	Charles Hatten	312-886-6031	312-886-5824
6	First International Bldg. 1202 Elm Street Dallas, TX 75270	AR, LA, NM, OK, TX	Mick Cote	214-665-7219	214-665-2164
7	324 E. Eleventh Street Kansas City, MO 64106	IA, KS, MI, NE	Ward Burns	913-551-7960	913-551-7065

EPA Region	EPA Address	States Included in Region	Regional Contact	Phone	Fax
8	1860 Lincoln Street Denver, CO 80295	CO, MN, ND, SD, UT, WY	John Dale	303-312-6934	303-312-6064
9	215 Freemont Street San Francisco, CA 94105	AZ, CA, HI, NV, Guam, American Samoa	Patricia Bowlin	415-744-1188	415-744-1076
10	1200 Sixth Avenue Seattle, WA 98101	WA, OR, ID, AK	John Keenan	206-553-1817	206-553-0110